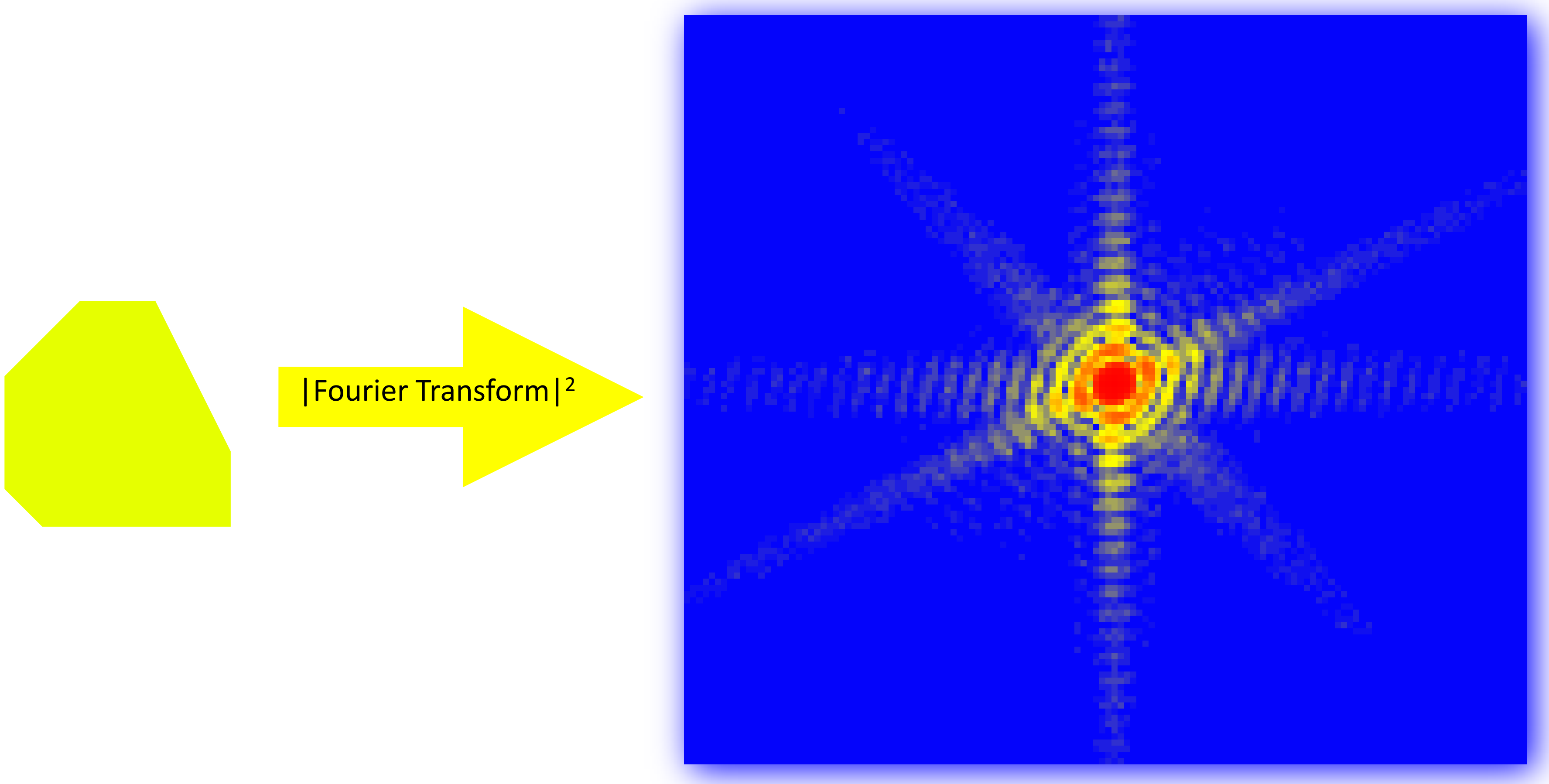
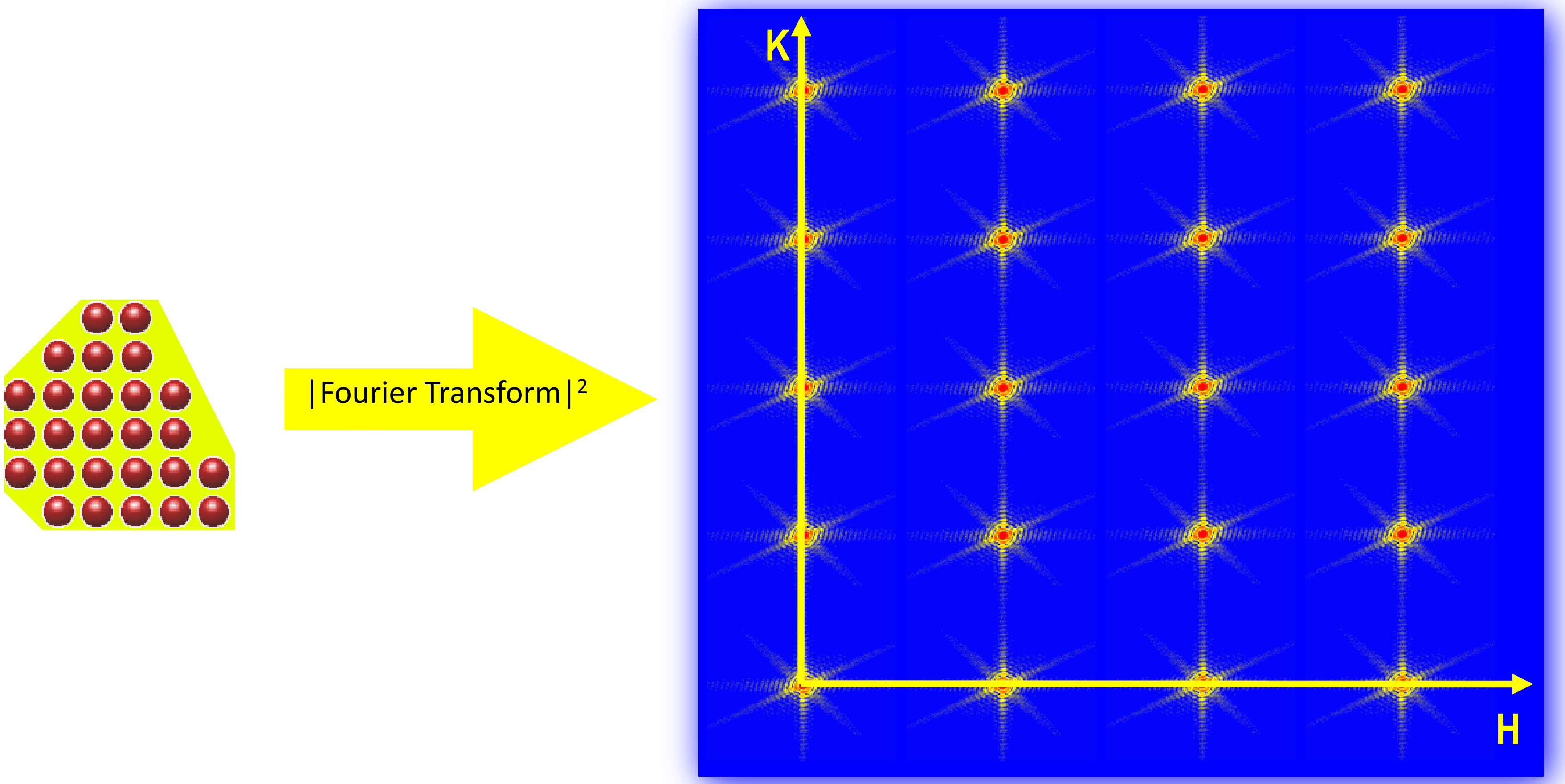
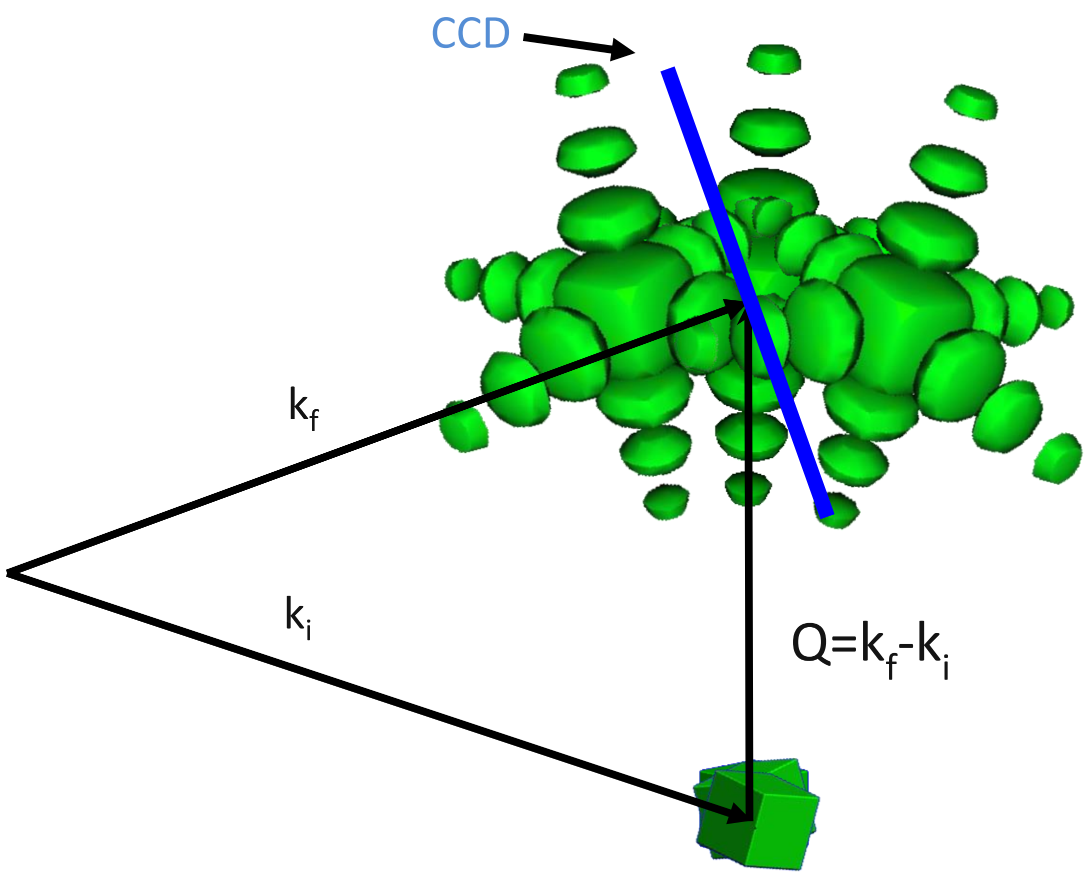
Coherent Diffraction from Crystals



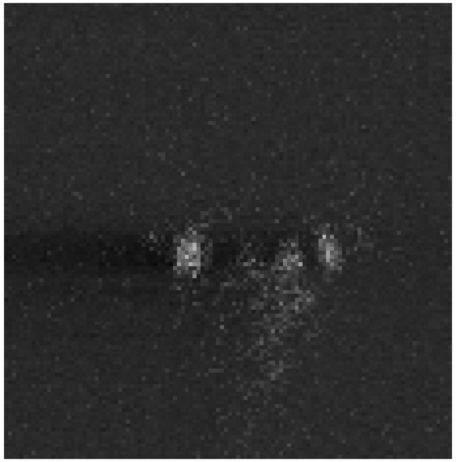
Coherent Diffraction from Crystals

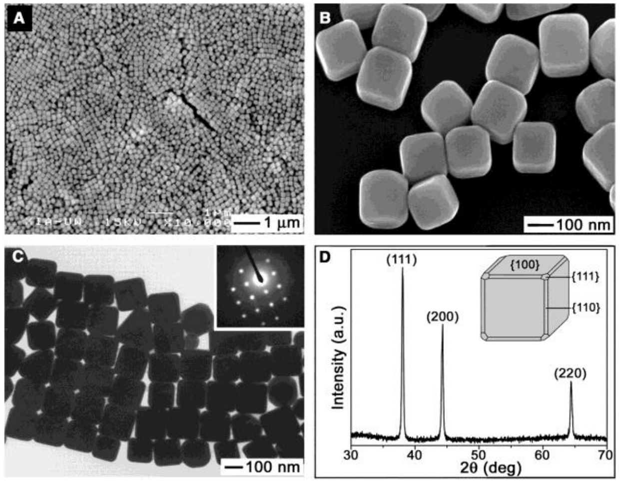


Measuring 3D CXD



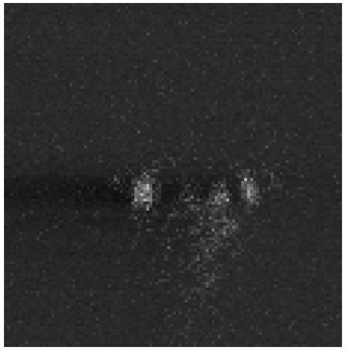
Silver Nano Cube (111)

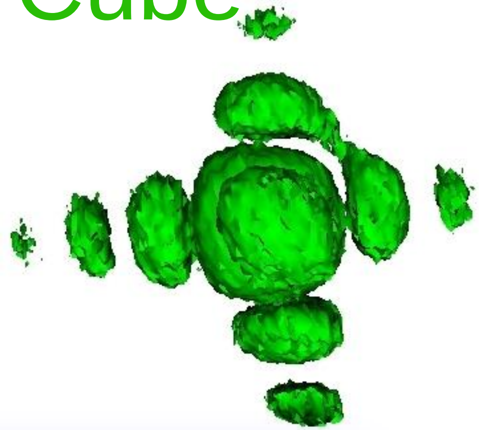


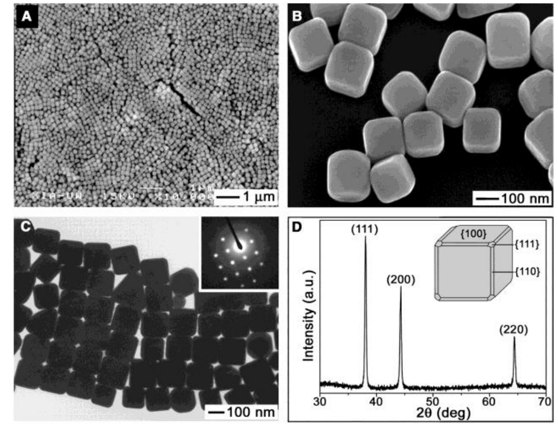


Yugang Sun and Younan Xia, Science 298 2177 (2003)

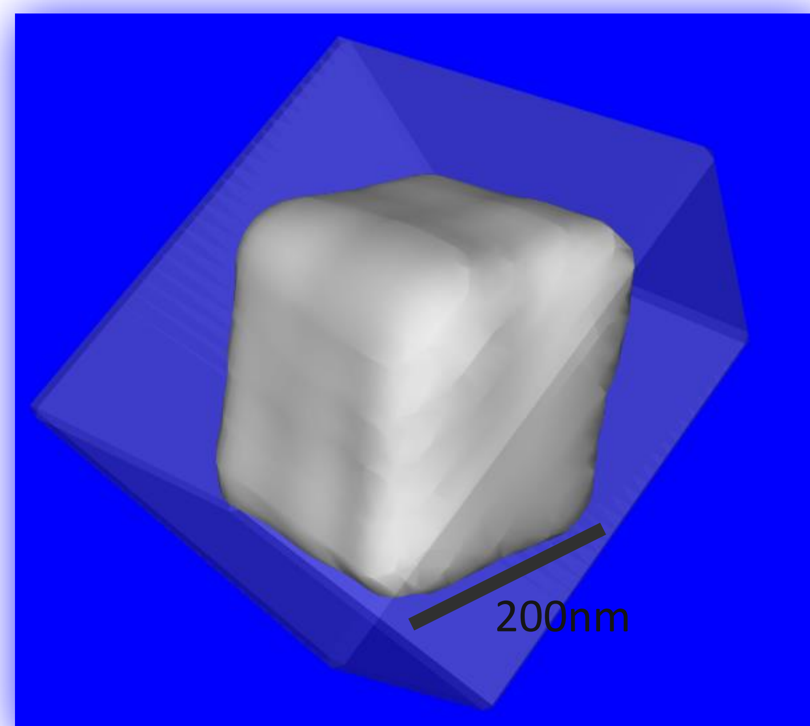
3D Ag Nano Cube

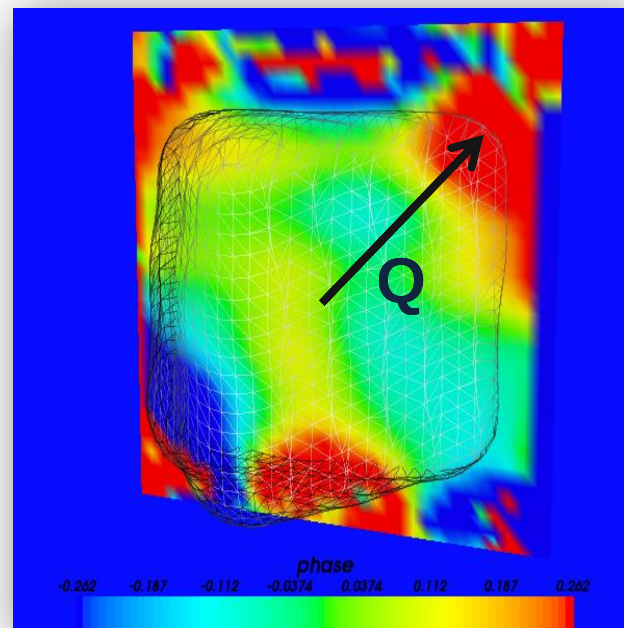




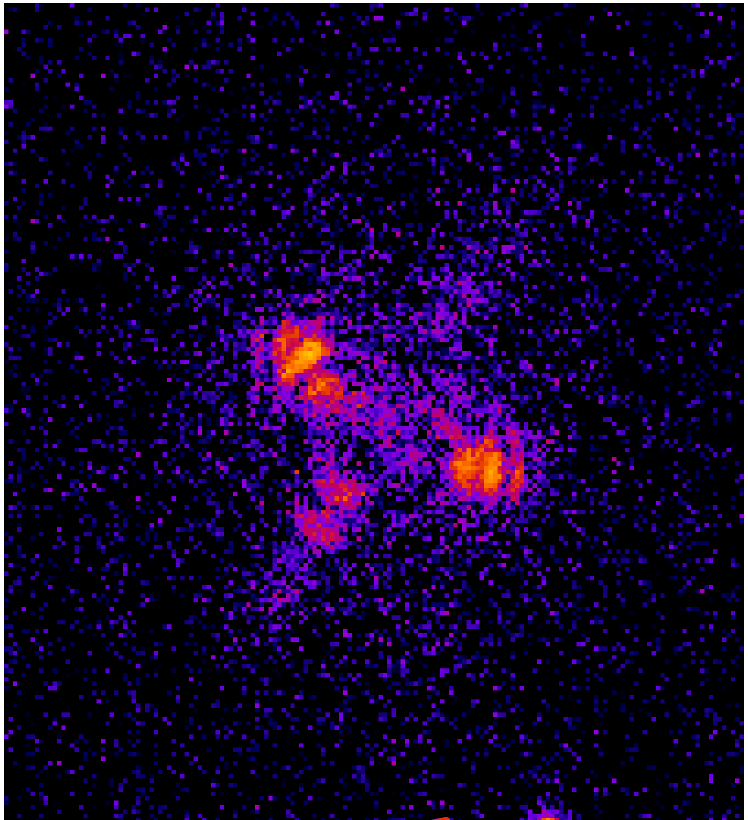


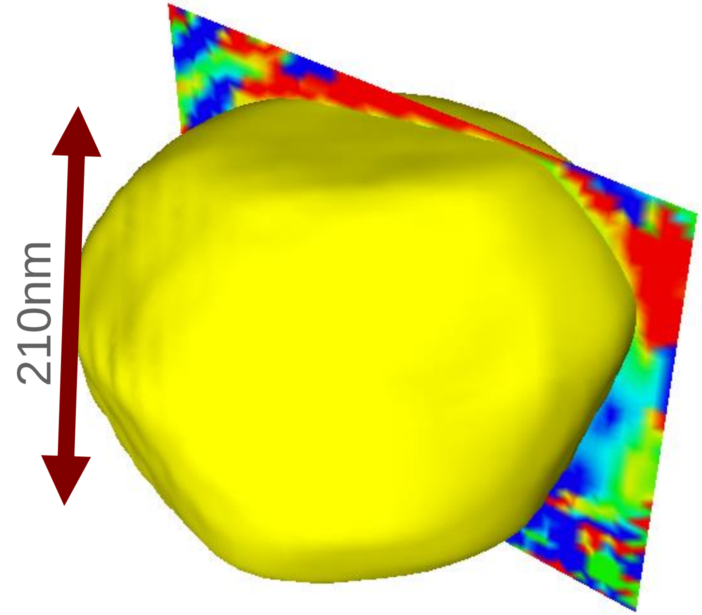
Yugang Sun and Younan Xia, Science 298 2177 (2003)

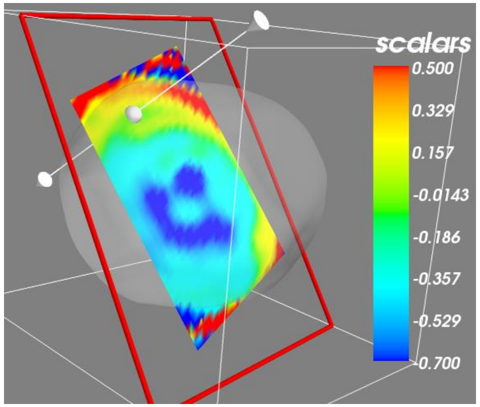


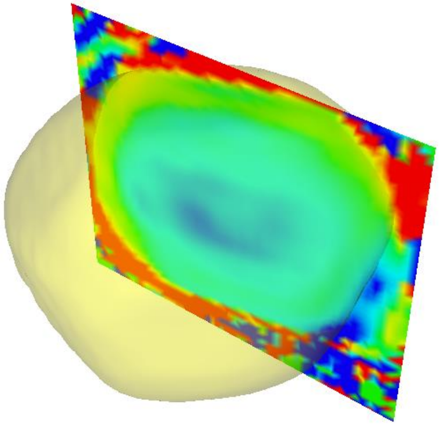


Hi Resolution Imaging?









~7nm data

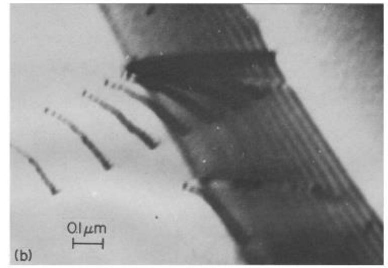
At APS 34-ID-C:
9.25 hours of scanning
0.64 hours of x-ray exposure

APS-MBA (100x) → 25 sec?

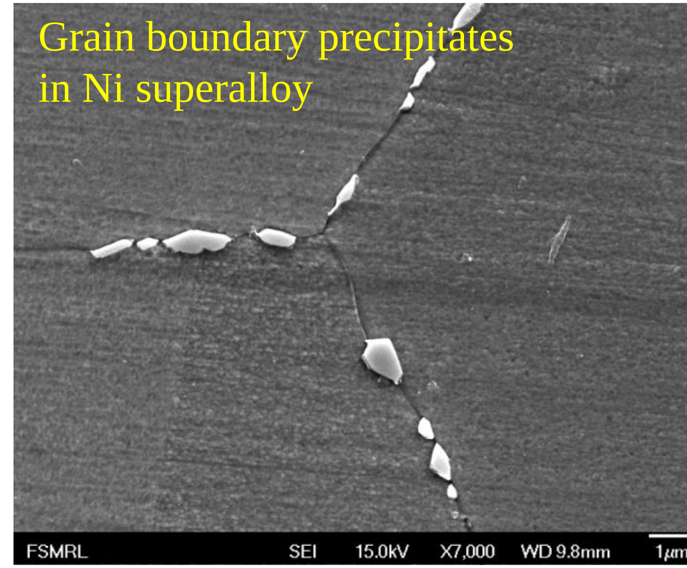
http://www.jwave.vt.edu/~rkriz/Projects/create_color_table/color_07.pdf

Slow Dynamics?

- 25 seconds is “almost” static on the scale of hours.
  - Grain Growth (annealing twins in fcc metals)
  - Defect annealing
  - Domain evolution
  - Surface Melting
  - Equilibrium Crystal Shapes
  - DAFS



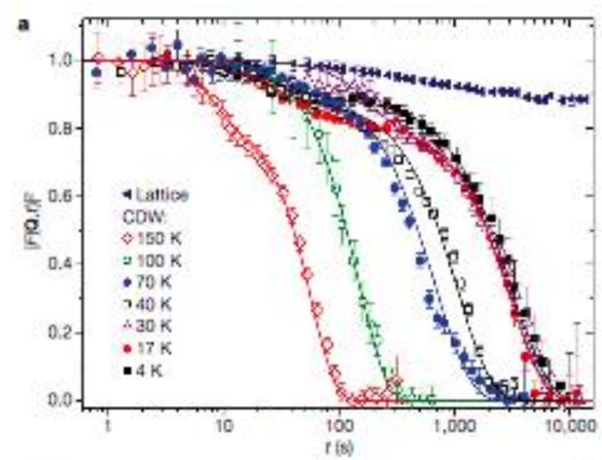
Meyers & Murr,
Acta Metallurgica (1977)

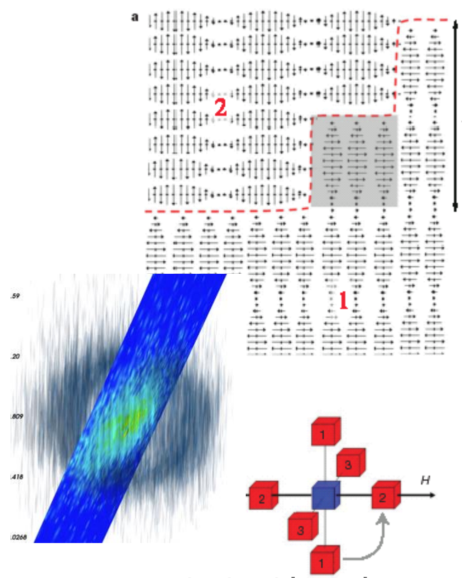


Courtesy of Jim Stubbins UIUC

$$f(\mathbf{Q},E) = [f_0(\mathbf{Q}) + f_a'(E) + i f_a''(E)] + [f_a''(E)\tilde{\chi}(E)].$$

Charge Density wave in Cr





O.G. Shpyrko et al.
Nature Vol. 447 (2007)

J. C. HEYRAUD and J. J. METOIS

Acta Metallurgica (1980)

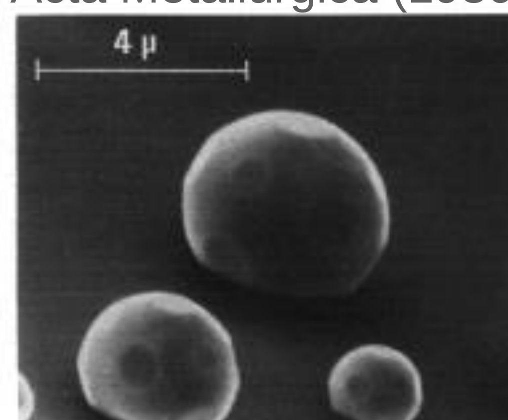
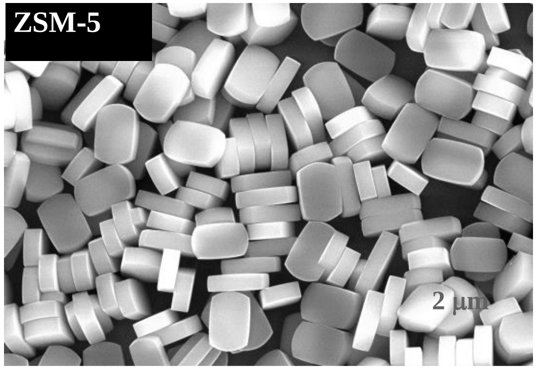
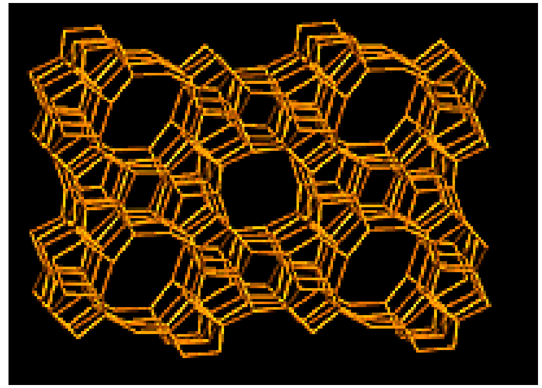


Fig. 2. Equilibrium shape of gold crystallites on graphite obtained after 70 h at 1273 K. Pressure ~10⁻⁸ torr.

ZSM-5 ($Si_{95.7}Al_{0.3}O_{192}$)

MFI





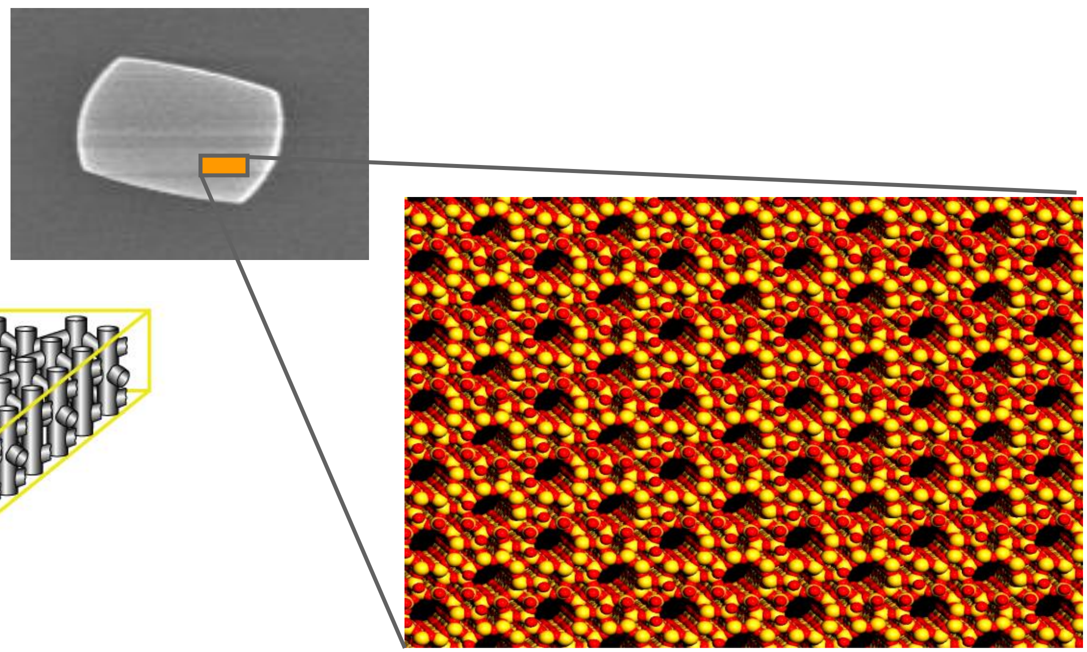
a=20.090Å

b=19.738Å

c=13.142Å

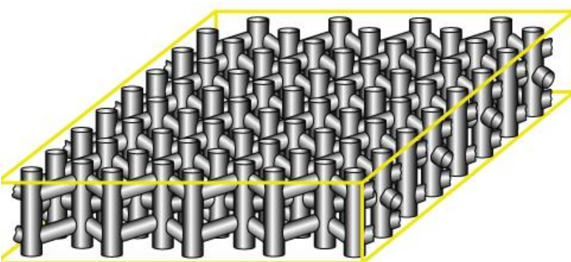
α=β=γ=90.0°

Orthorhombic

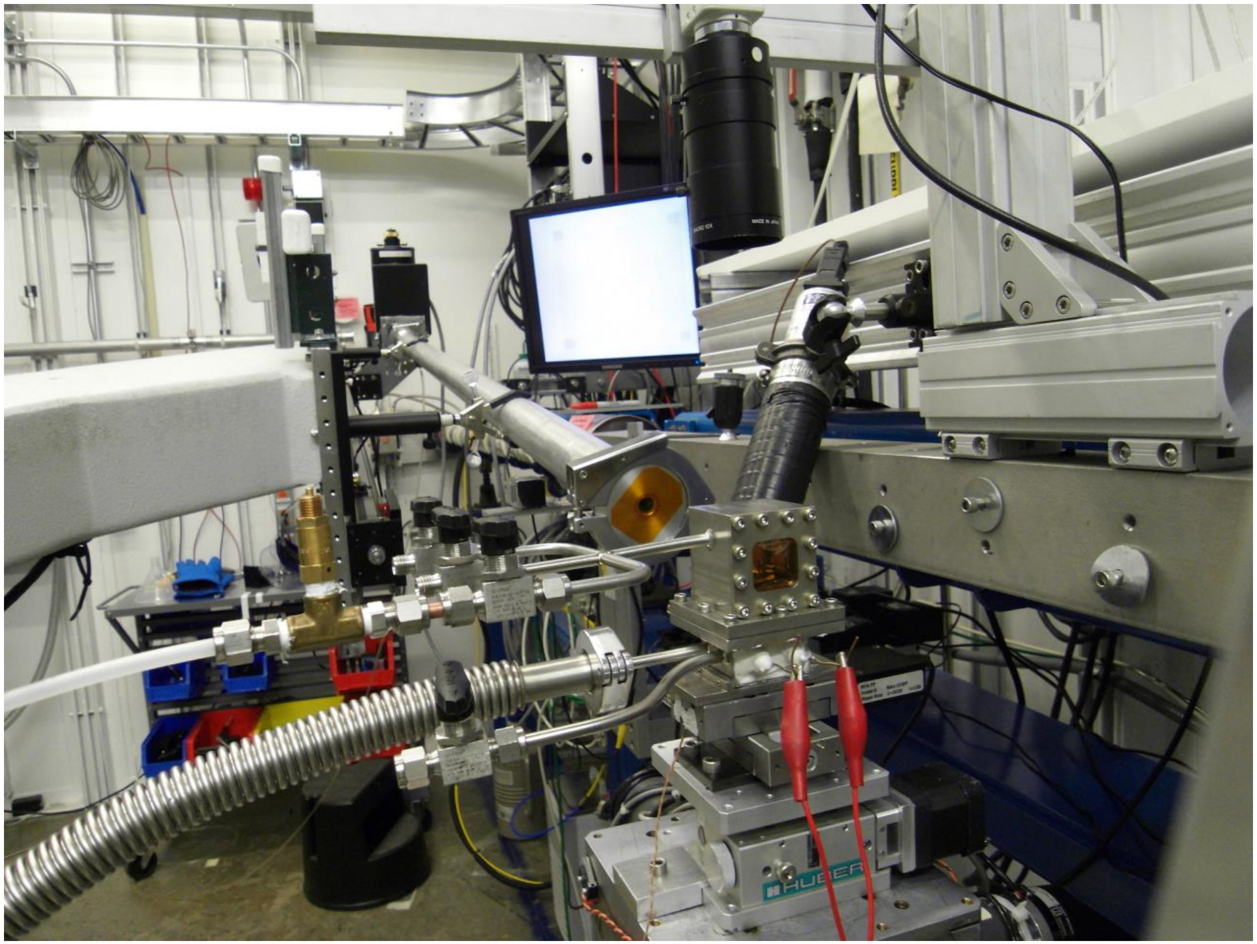


0.56 nm

Hydrophobic channels

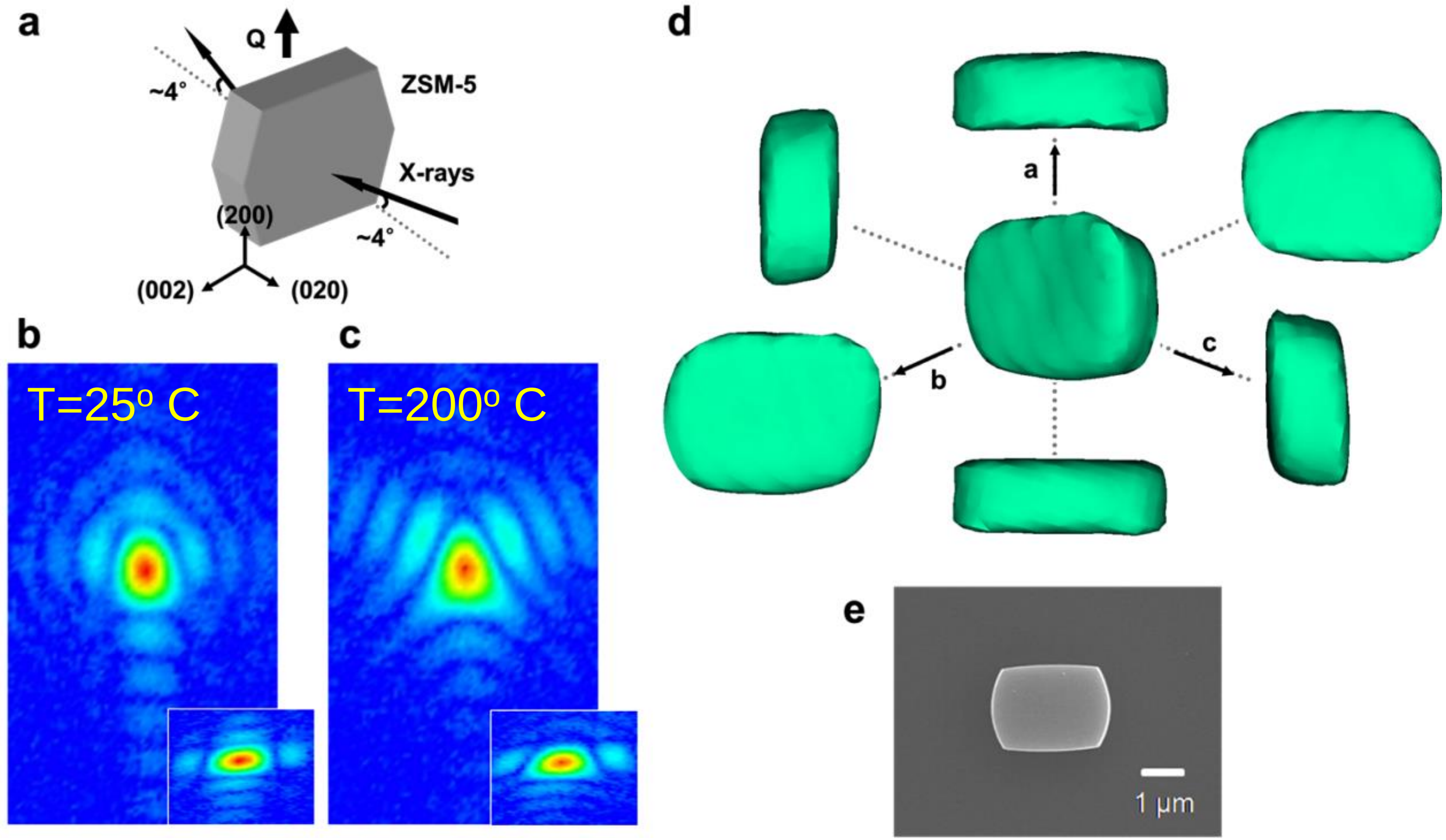


CXD Imaging of Zeolites as a function of temperature



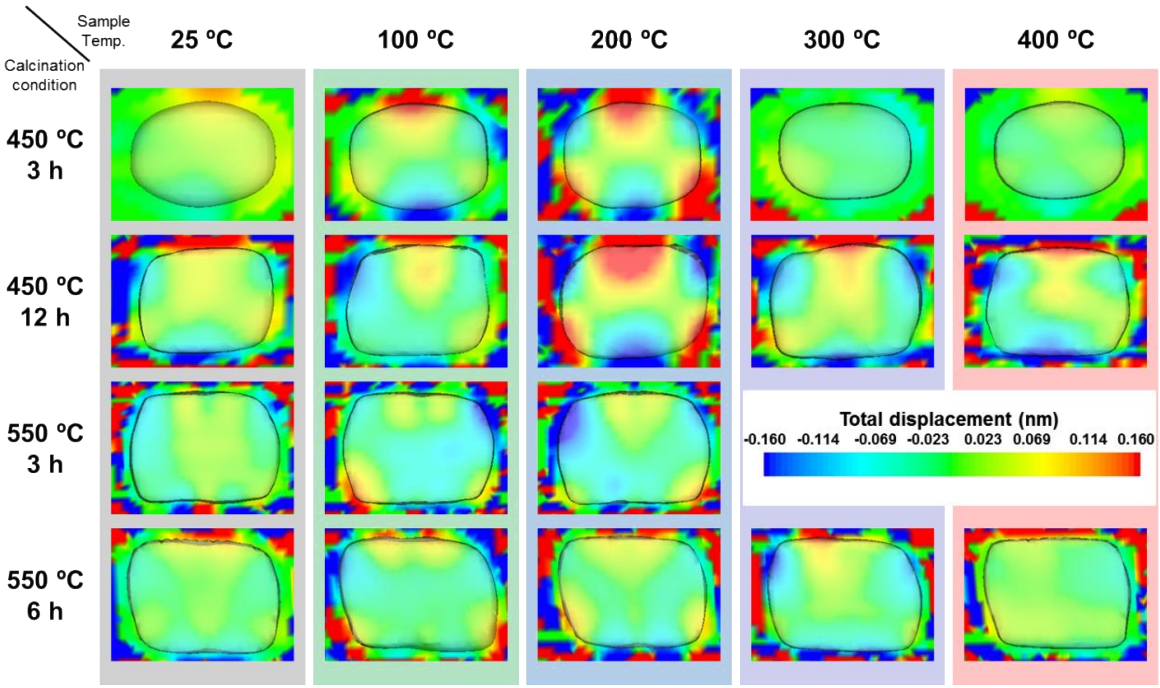
Cha, W., Song, S., Jeong, N. C., Harder, R., Yoon, K. B., Robinson, I. K., & Kim, H. (2010). *New Journal of Physics*, *12*(3), 035022.

CXD Imaging of Zeolites as a function of temperature



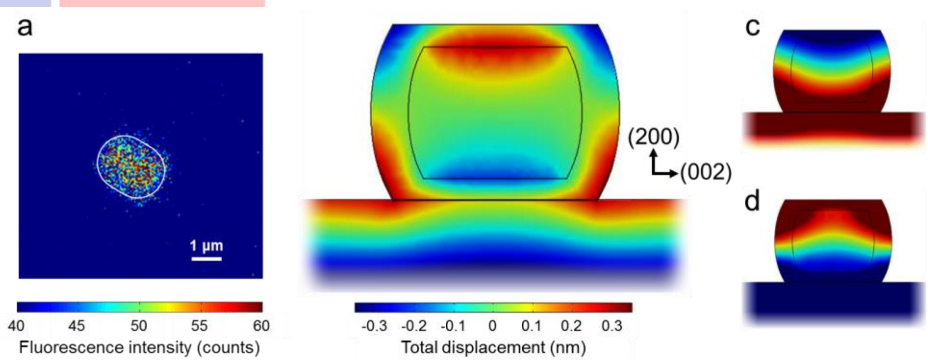
Wonsuk Cha, Nak Cheon Jeong, Sanghoon Song, Hyun-jun Park, Tung Cao Thanh Pham, Ross Harder, Bobae Lim, Gang Xiong, Docheon Ahn, Ian McNulty, Jungho Kim, Kyung Byung Yoon, Ian K Robinson, and Hyunjung Kim
(2013). Core–shell strain structure of zeolite microcrystals. *Nat Mater*, *12*(8), 729–734.

CXD Imaging of Zeolites as a function of temperature



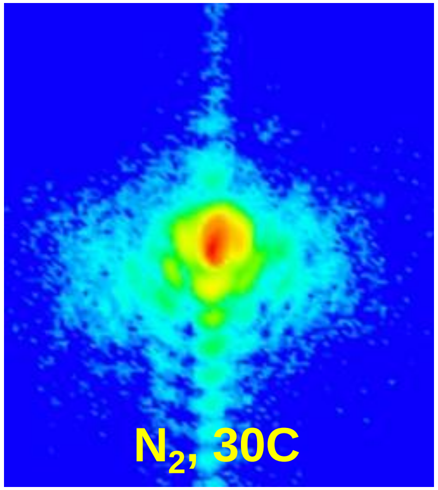
Lattice deforms as a function of temperature and calcination process

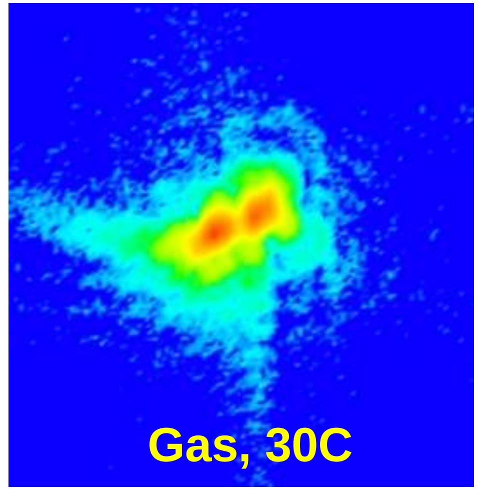
FEA modeling of ZSM-5
& fluorescent optical microscopy

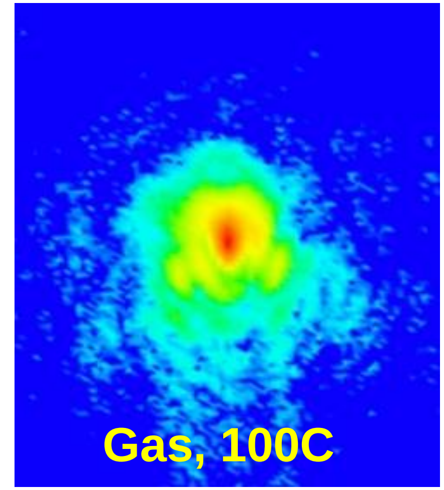


Wonsuk Cha, Nak Cheon Jeong, Sanghoon Song, Hyun-jun Park, Tung Cao Thanh Pham, Ross Harder, Bobae Lim, Gang Xiong, Docheon Ahn, Ian McNulty, Jungho Kim, Kyung Byung Yoon, Ian K Robinson, and Hyunjung Kim
(2013). Core–shell strain structure of zeolite microcrystals. *Nat Mater*, *12*(8), 729–734.

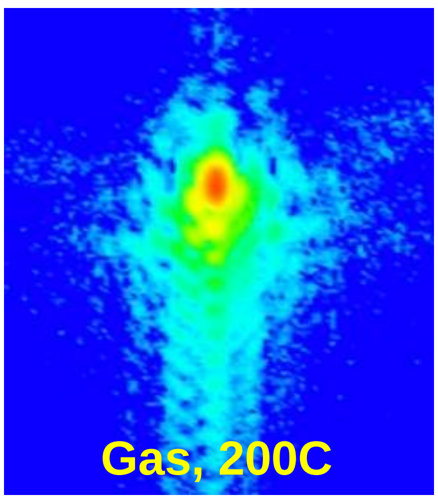
Cu-ZSM-5 for Nitric Oxide Reduction

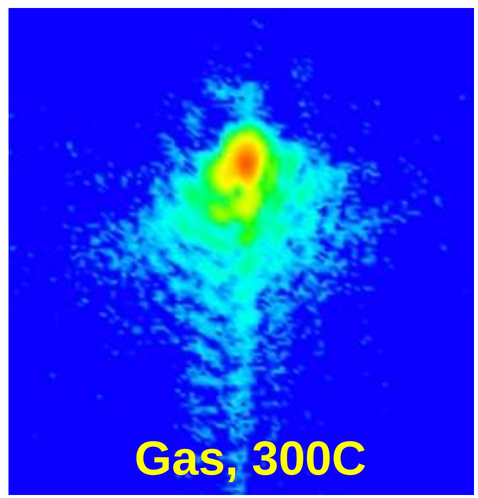


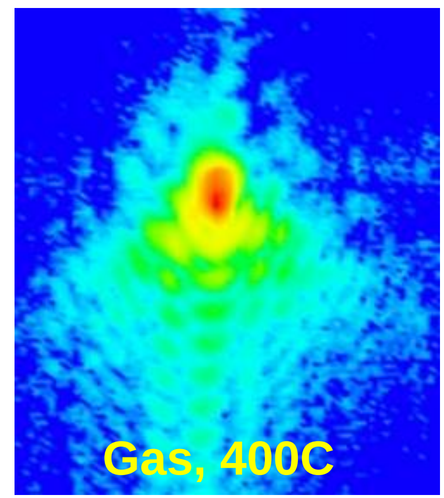




NO 3% C3H6 1%   O2 7%

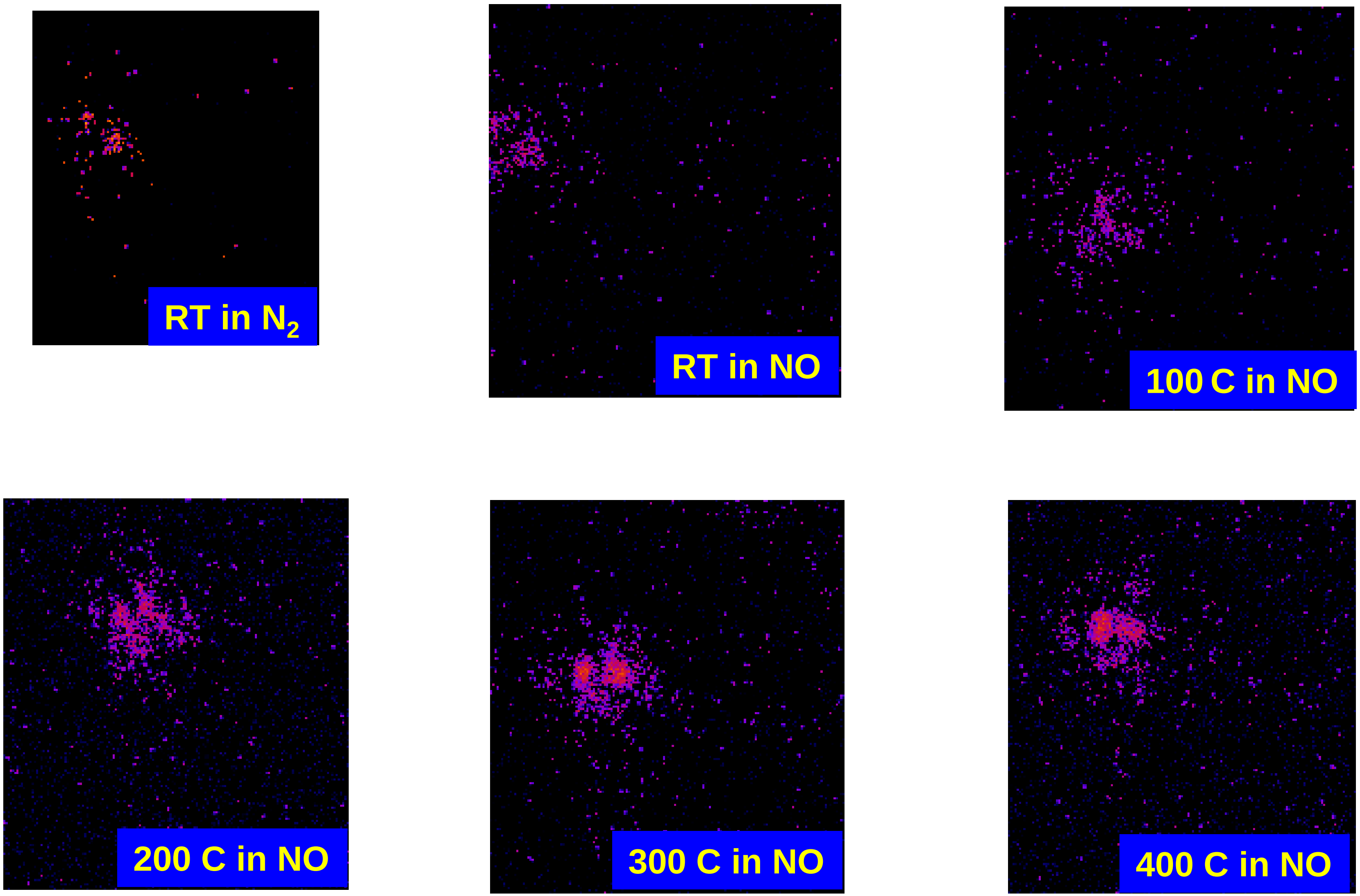




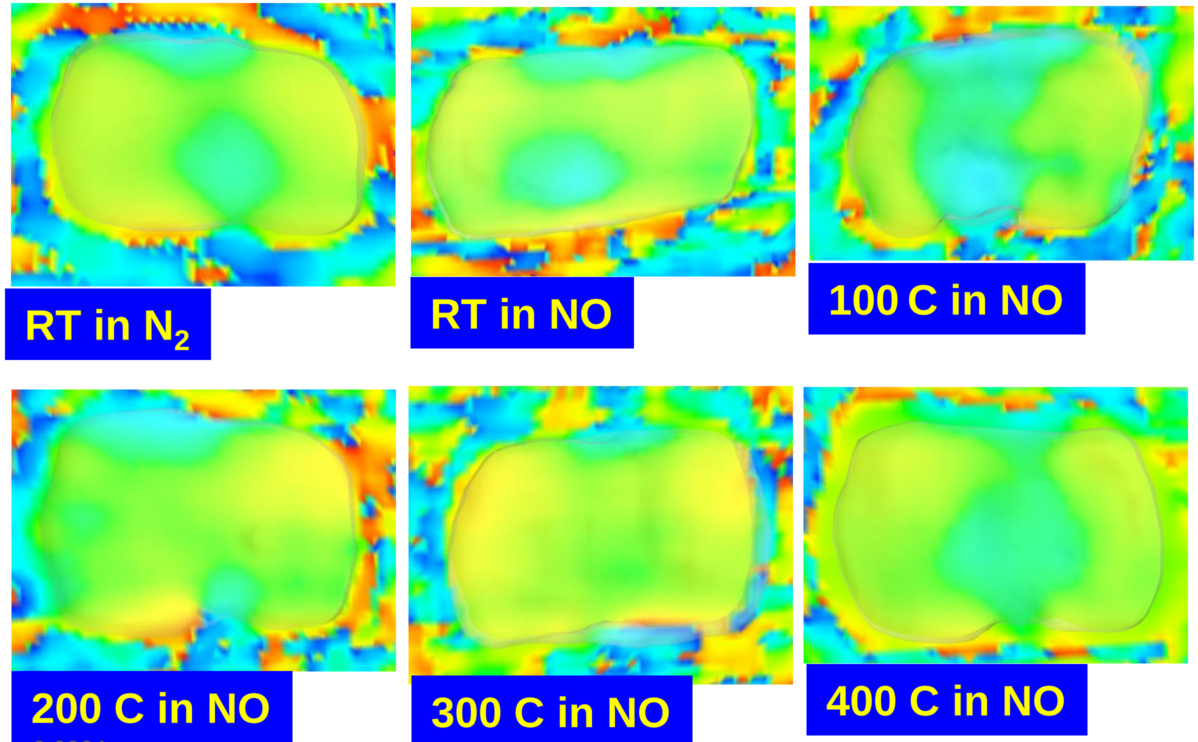


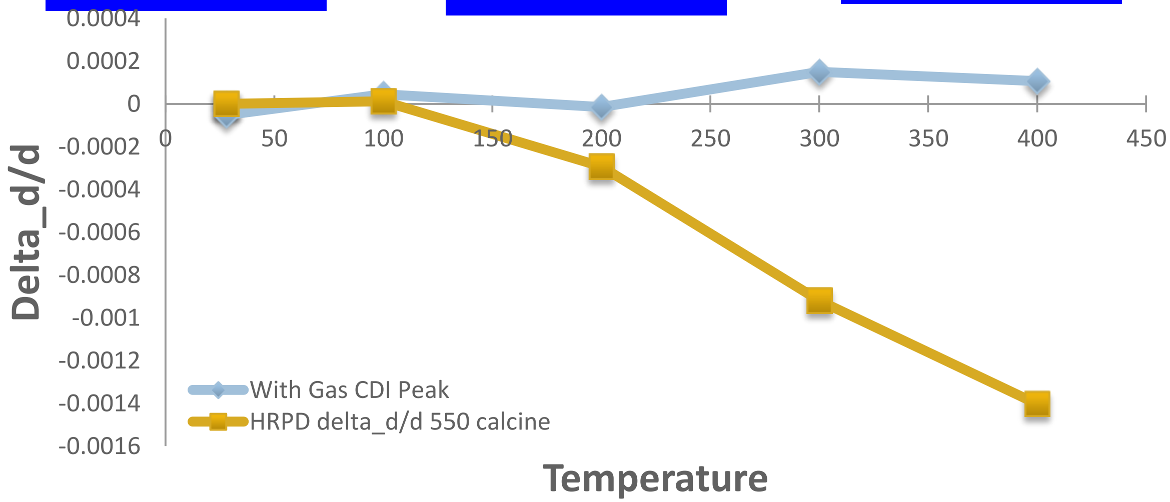
Gruenert, W., et al. (1994). Structure, Chemistry, and Activity of Cu-ZSM-5 Catalysts for the Selective Reduction of NOx in the Presence of Oxygen. *The Journal of Physical Chemistry*, *98*(42), 10832–10846.

Cu-ZSM-5 for Nitric Oxide Reduction

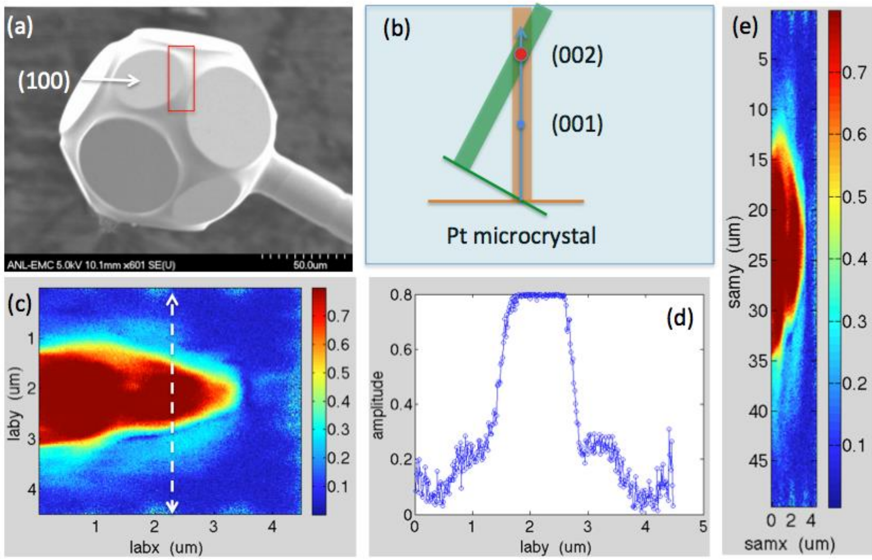


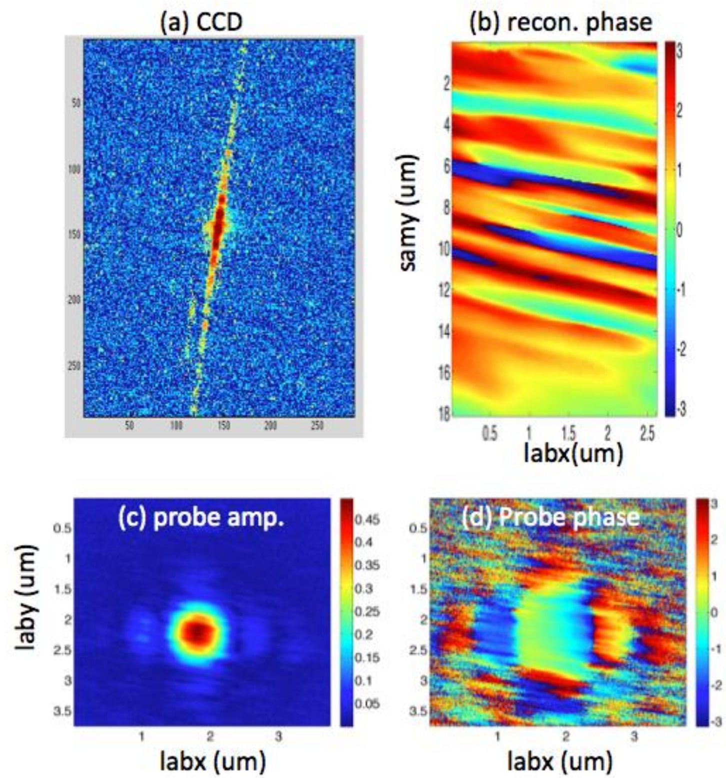
Cu-ZSM-5 for Nitric Oxide Reduction



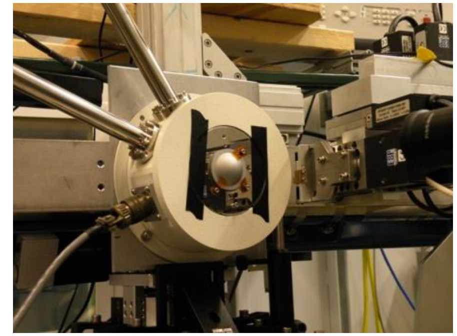


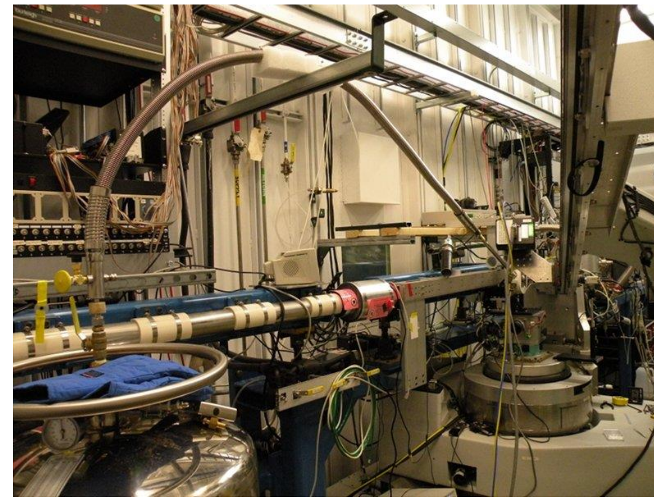
Surface diffraction Coherent Imaging



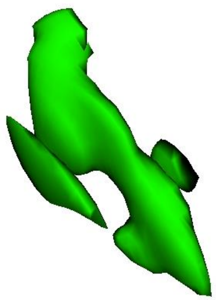


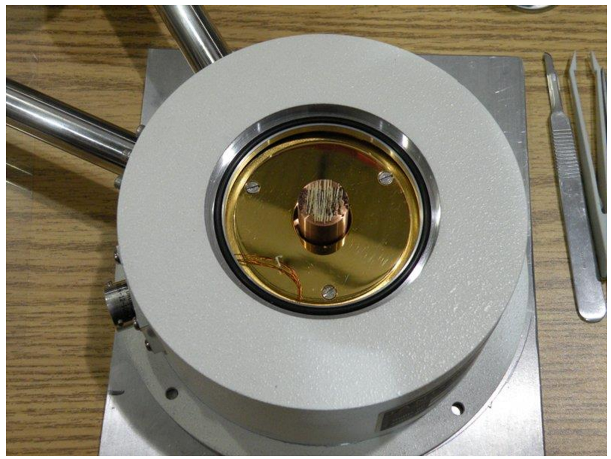
Thank You



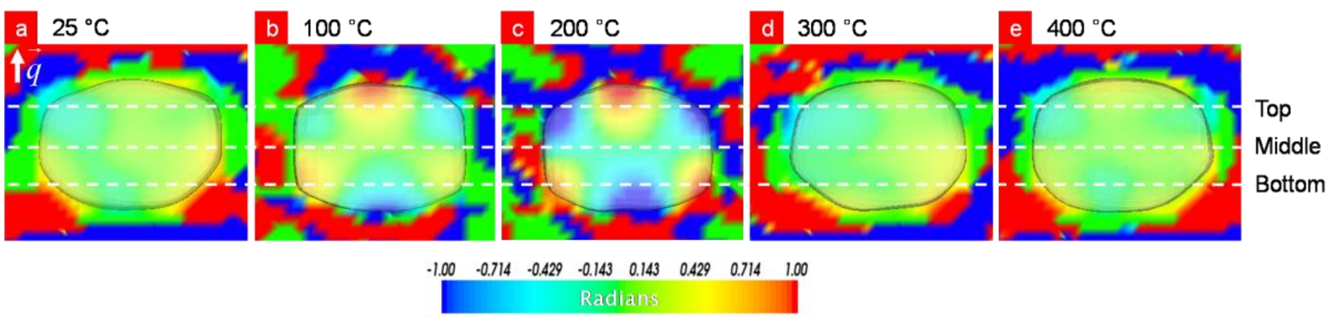


Calcium Oxalate in maize stover





Strain in ZSM-5 Zeolite

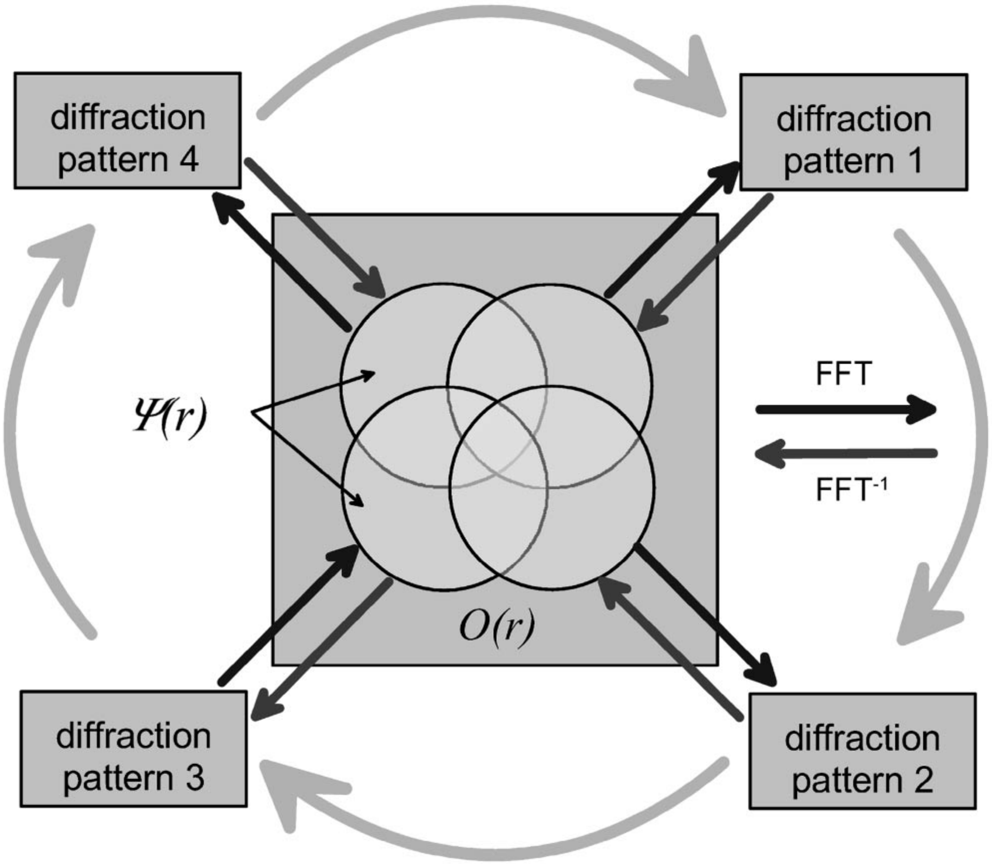


Use of the Advanced Photon Source was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

Coherent Imaging of Extended Samples

Ptychography

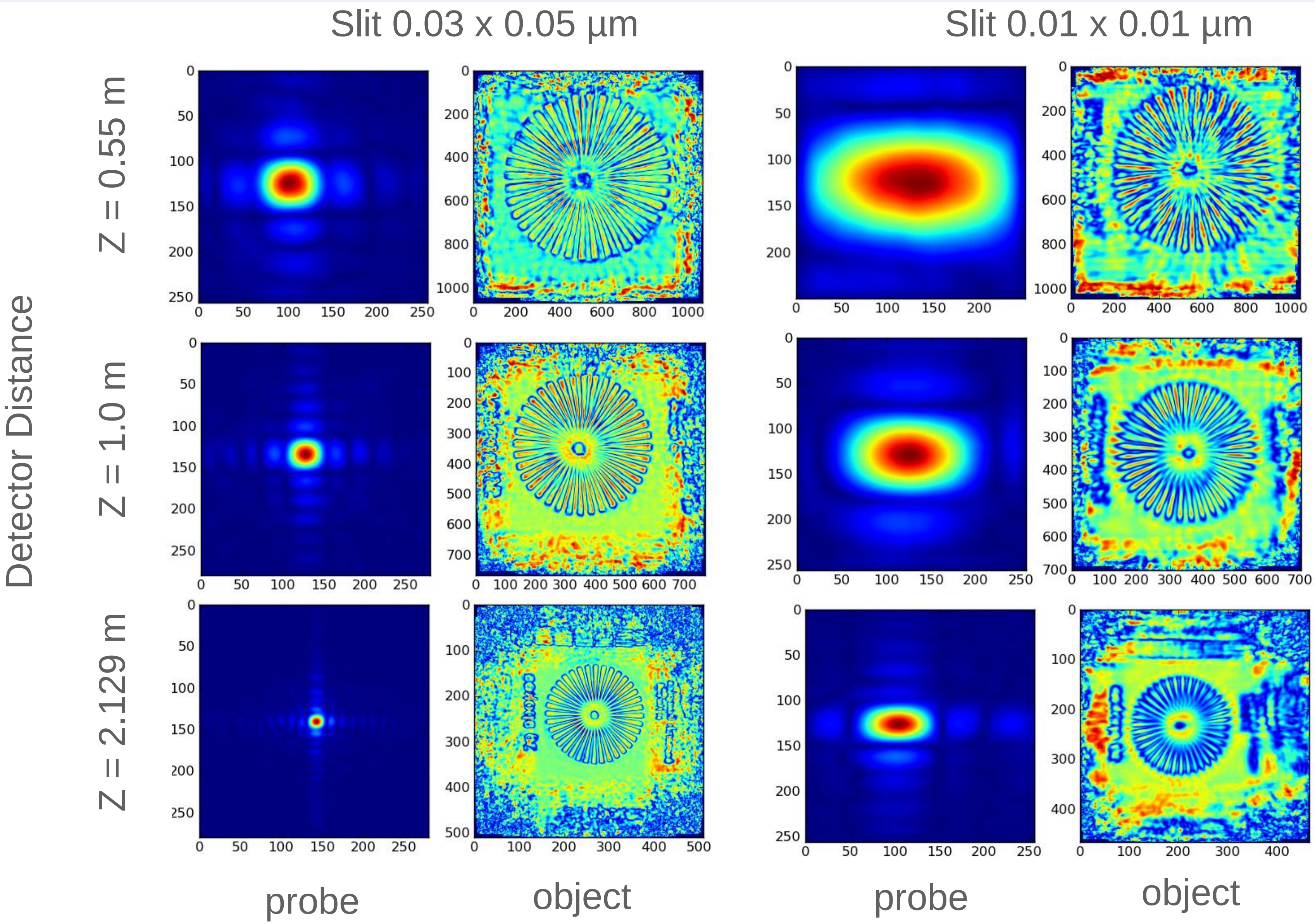
- "Arbitrary" field of view
- Quantitative phase information
- Simultaneous image of sample illumination



Rodenburg, J., et al. (2007). *Physical review letters*, *98*(3), 034801.
Thibault, et al. (2008). *Science*, *321*(5887), 379–382.

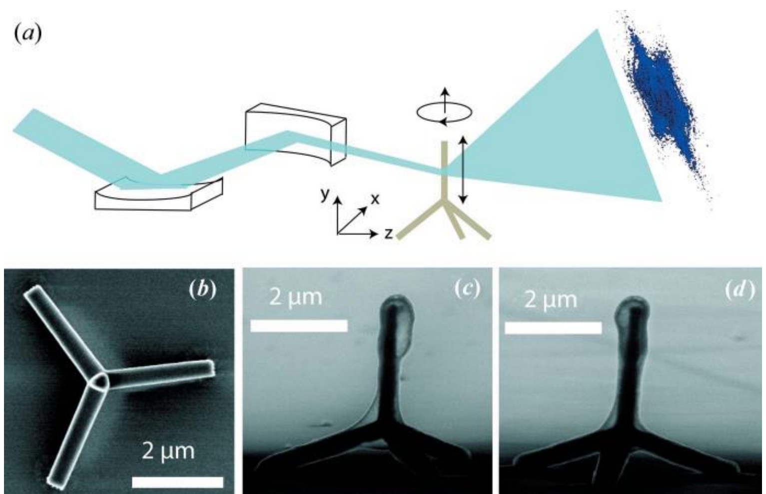
Huang, X.,Harder, R., et al. (2012).
Quantitative X-ray wavefront measurements of Fresnel zone plate and K-B mirrors using phase retrieval.
Opt. Express, *20*(21), 24038–24048.

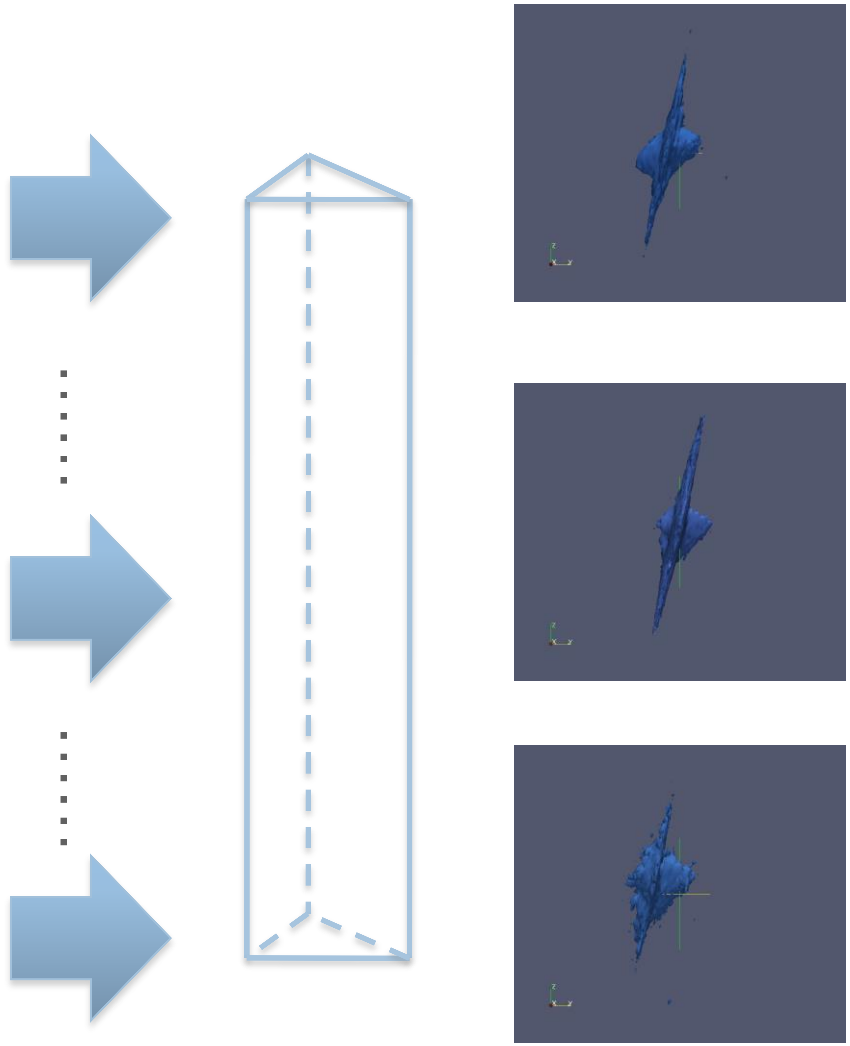
Coherent Imaging of Extended Samples



1D Bragg Ptychography

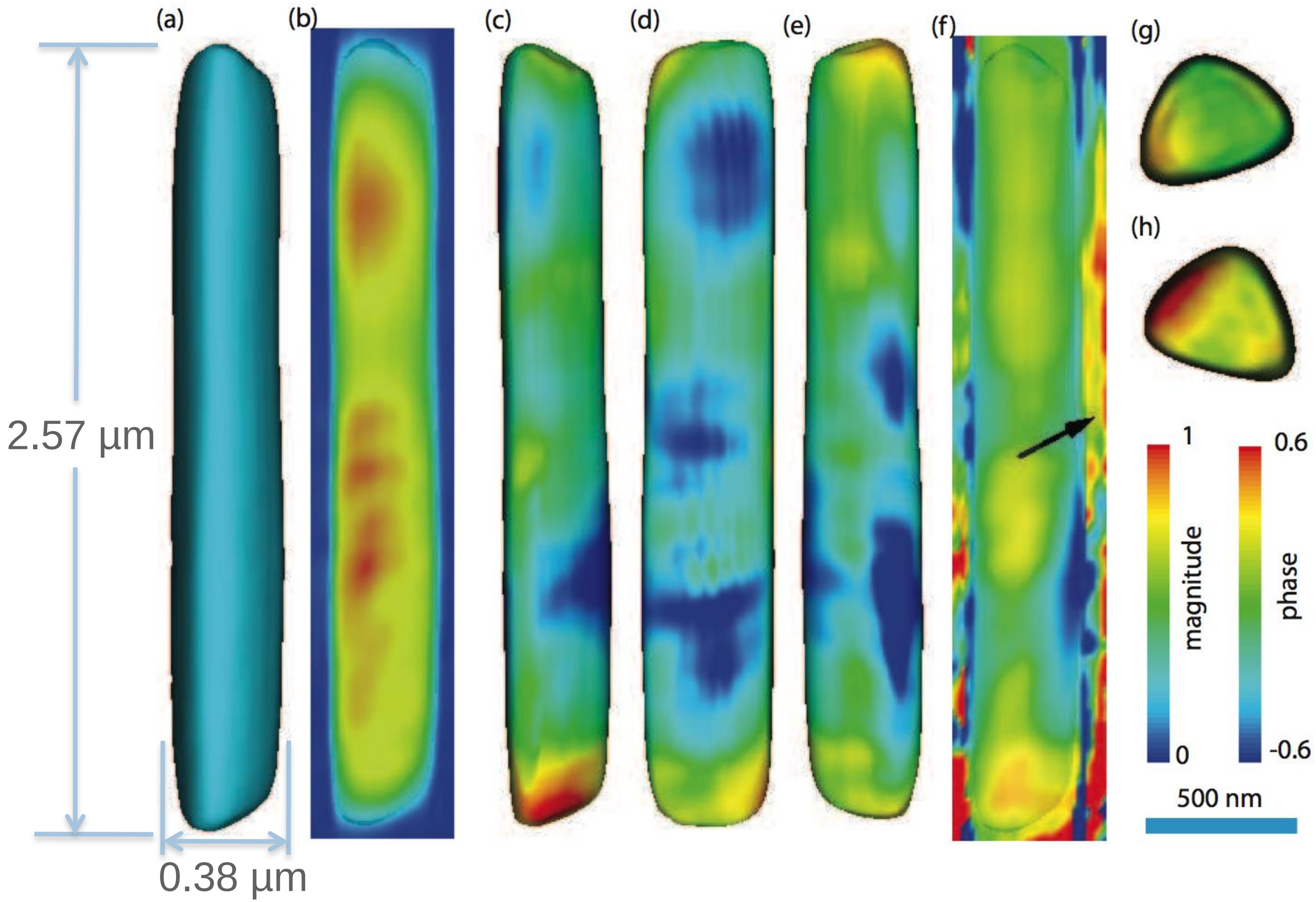
- Ptychographical scan along the vertical arm of ZnO tetrapod
- focused beam ~ 1.3 µm.
- step size < 0.5 µm .
- At each scan position, 3D diffraction pattern collected with 11.5 keV x-rays.
- Binned effective array size for each scan: 128x96x128.
- Real-space voxel size: 14x19x14 nm.



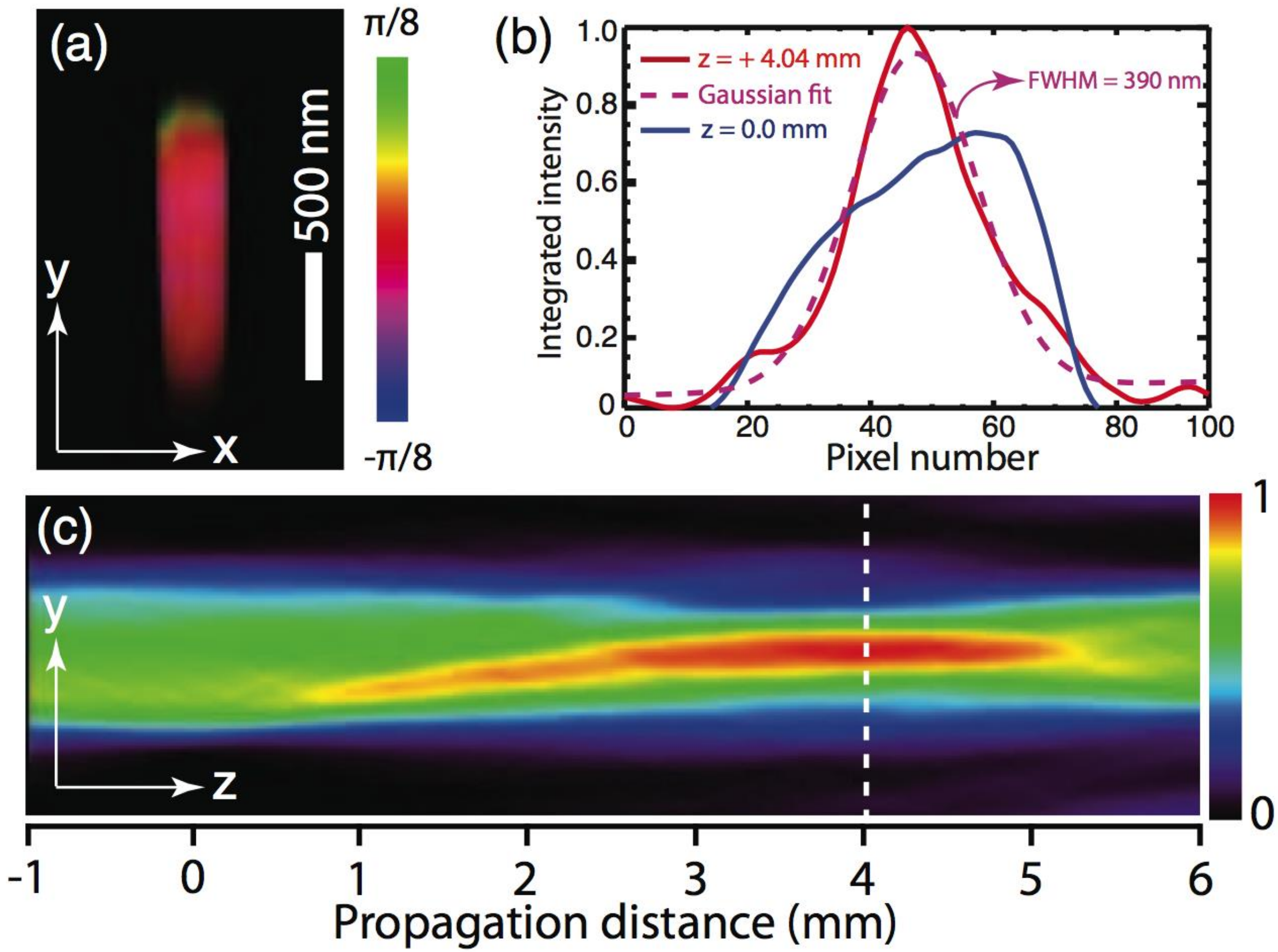


X. Huang, et. al., J. Appl. Crystal., 45, 778-784, (2012).

1D Bragg Ptychography - Image

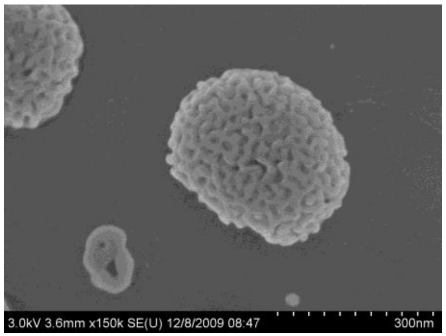


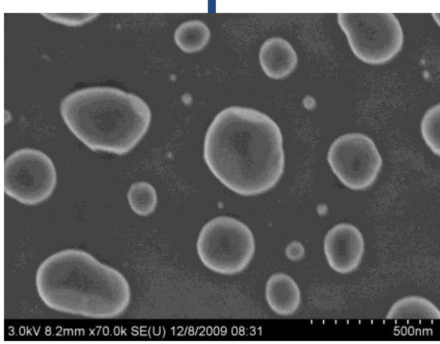
1D Bragg Ptychography - Probe



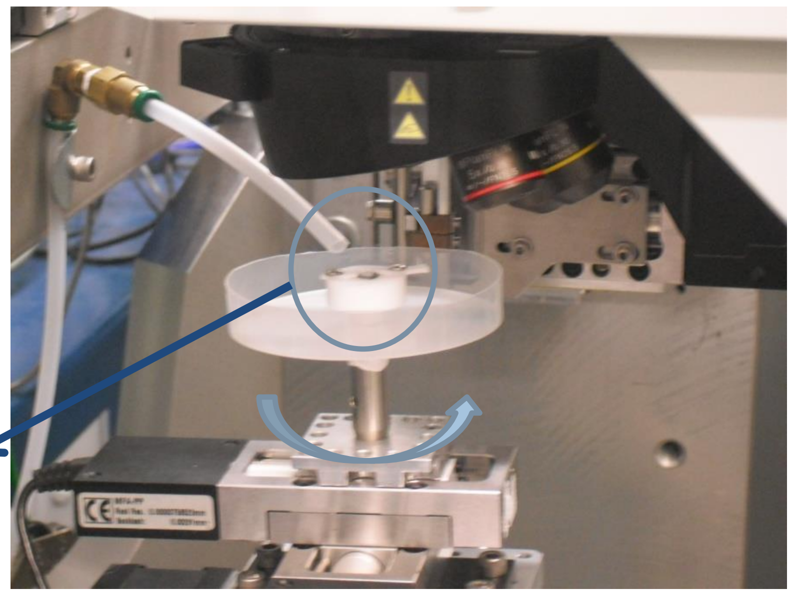
Nanoporous Gold structural evolution

To study strain at the alloy-pore interface we have begun to image nano-crystals of gold-silver at different stages of dealloying.

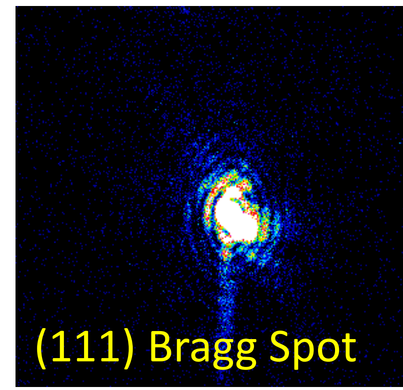




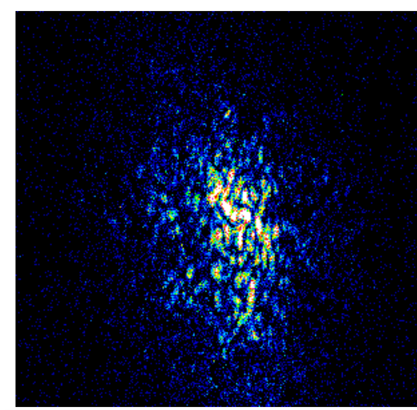
In-place dealloying to maintain the position of 300nm crystals in the 1um focused x-ray beam



Rotate ±<1°to record the whole Bragg spot

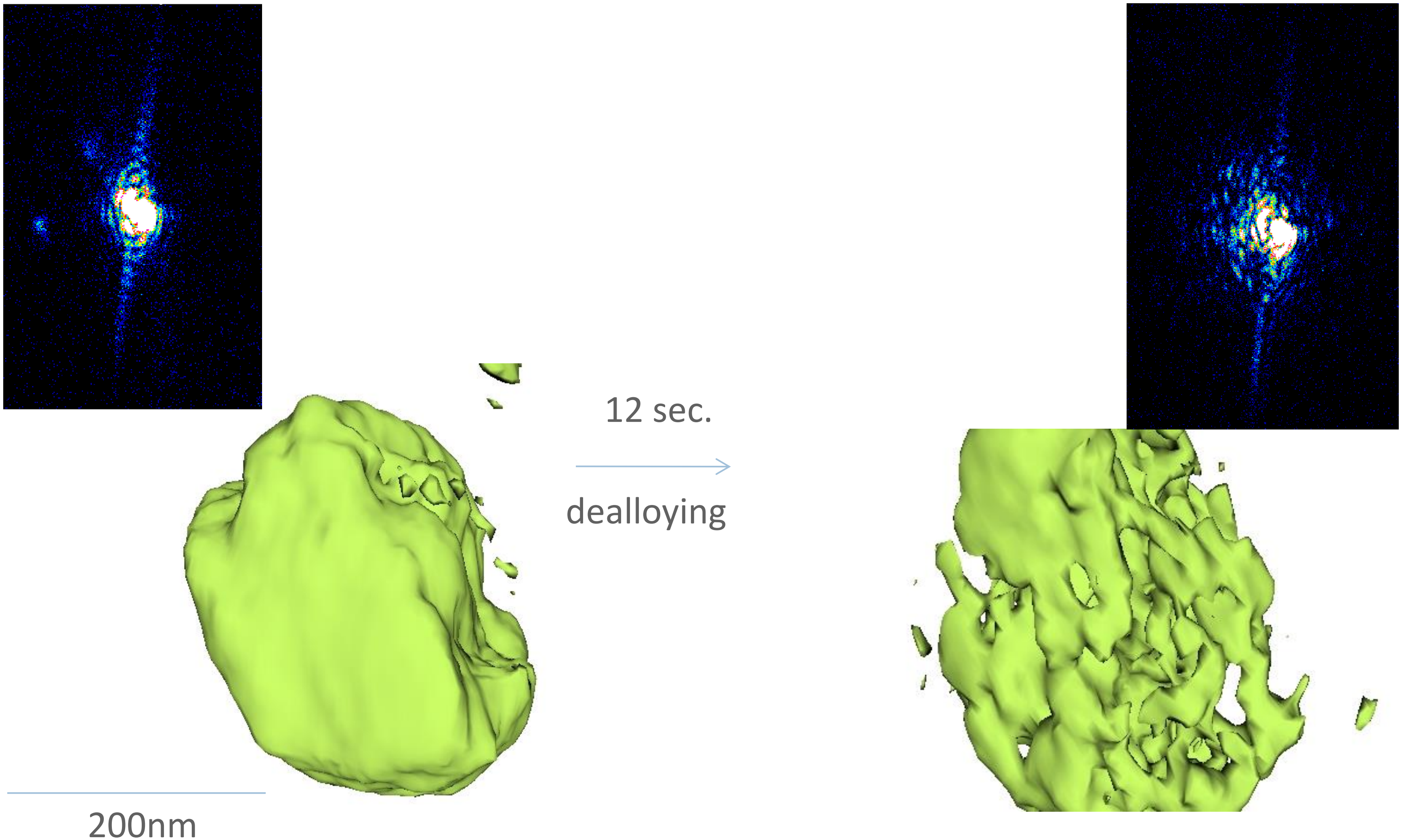


~30 sec. dealloying



Courtesy: Y.K. Chen (NWU), D. Dunand (NWU), I. McNulty, R. Harder

Nanoporous Gold structural evolution



Courtesy: Y.K. Chen (NWU), D. Dunand (NWU), I. McNulty, R. Harder